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Title: Fusion / LANL

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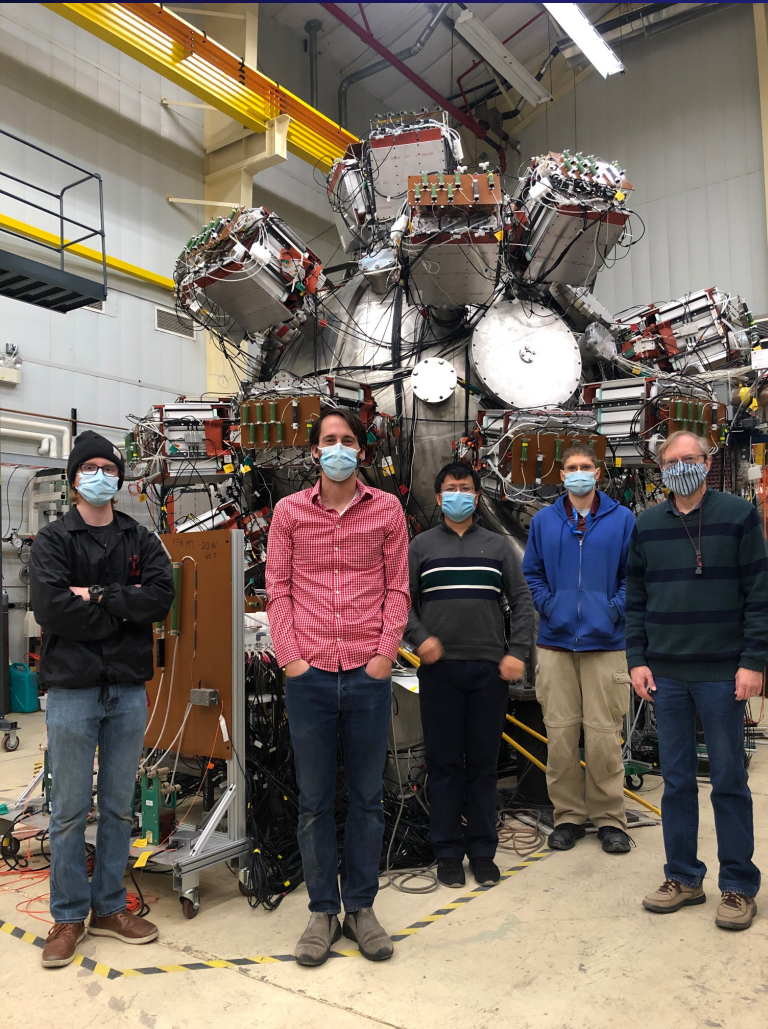
Intended for: Disseminate to Chevron Alliance

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Fusion / LANL



Samuel Langendorf

11/11/2020

OS
TORY

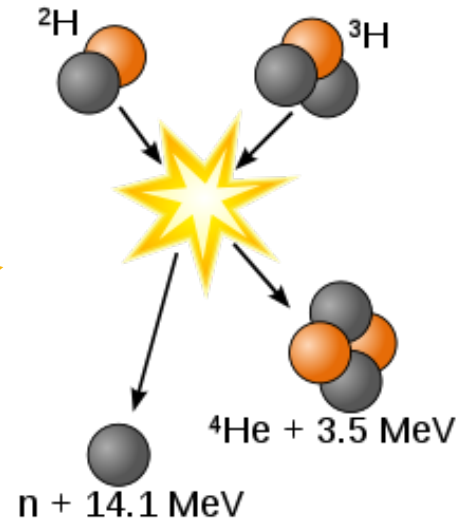
Fusion Energy

“Holy grail” of energy:

- Process that powers the sun and other stars, and fusion bombs
- Carbon-free
- Plentiful, power-dense fuel, e.g., 1 m³ seawater contains 33 g deuterium, equivalent to 400,000 kg of coal*
- No long-half-life waste**
- No intrinsic “runaway” or “meltdown” behavior... due to **high temperatures required!**

10 keV \approx 100,000,000 K !

Deuterium-Tritium fusion reaction:

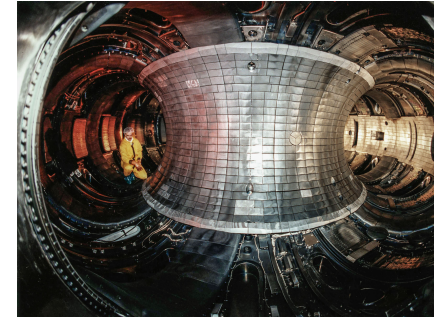


“Confinement”

Need significant efforts to achieve and contain such high temperatures:

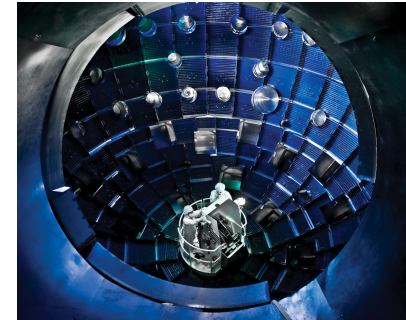
- **Magnetic confinement** – trap / levitate a fusion fuel plasma with strong magnetic fields, heat to fusion conditions with RF, beams, etc
- **Inertial confinement** – Compress and heat the fusion fuel rapidly enough to outrun thermal losses and ignite the fuel
- **Magneto-inertial confinement** – Blend of the two above approaches, compress and heat a magnetized target plasma

Tokamaks,
(Stellarators),
(Mirrors),



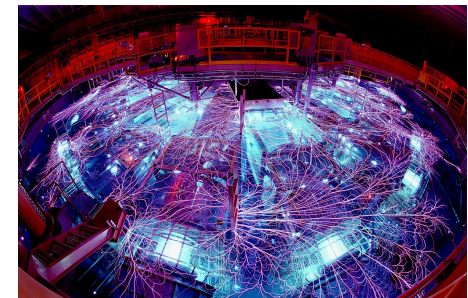
TFTR at Princeton Plasma Physics Lab

High-Power
Laser
Facilities:



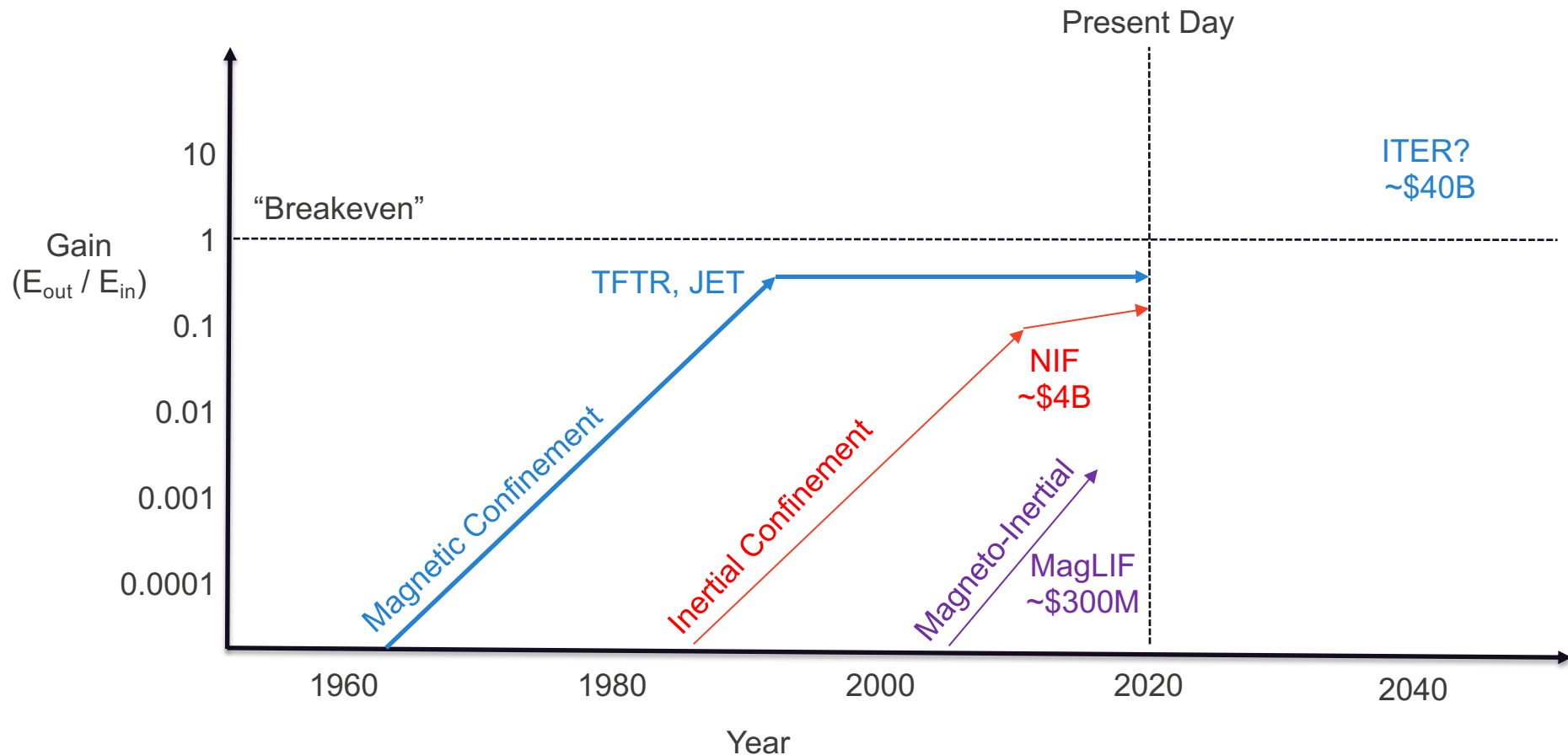
National Ignition Facility (NIF) at LLNL

Electrical
Pulsed Power
Machines:



Z Machine at Sandia National Labs

Historical progress in fusion confinement



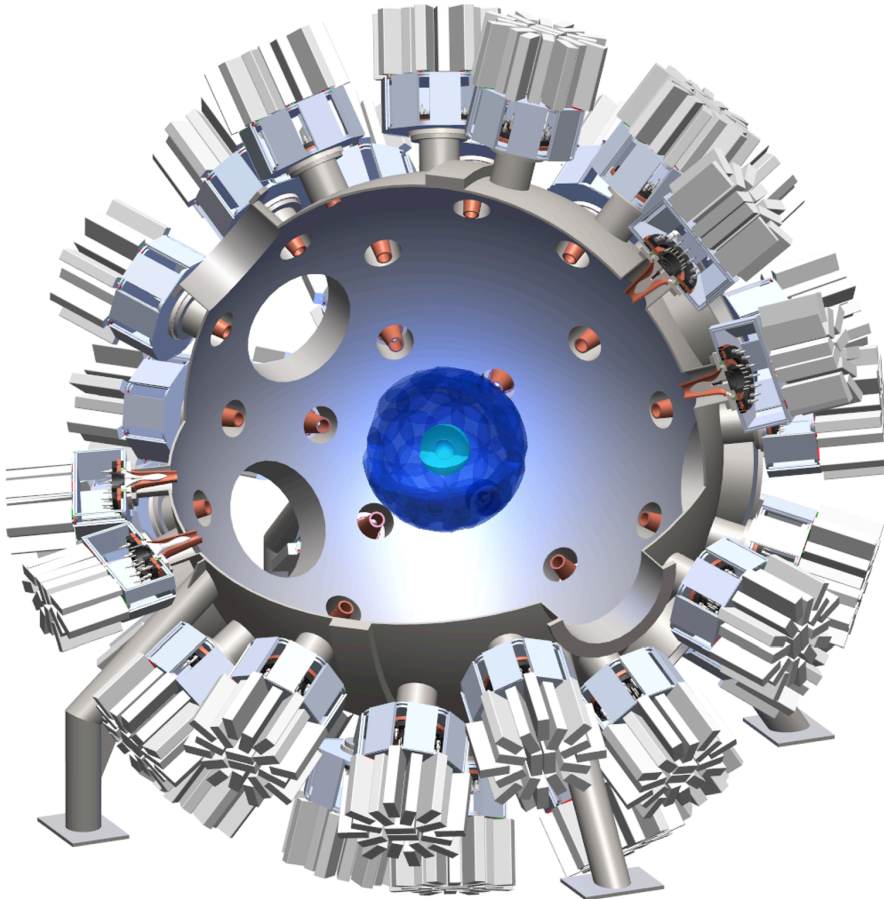
There is LANL involvement, though not ownership, in these fields to different degrees:
Glen Wurden, Scott Hsu, Xianzhu Tang, ICF folks, Kevin Yates, Materials folks...

Fusion startups

- There are also fusion startups, trying to disrupt the historical paradigm (which is slow and costly) and accelerate progress towards fusion
- **The originals:** Tri-Alpha Energy, General Fusion
 - Have been around for about 20 years
 - Have raised substantial private funding, e.g. I believe that TAE is at >\$100M / year scale
- **ARPA-E:**
 - Government funded ALPHA and BETHE programs, also OPEN funding
 - ALPHA / BETHE are \$30M / 3 years to promote innovative fusion concepts
 - **PLX:** active fusion project at LANL under BETHE award
- **New players:** Zap Energy, Commonwealth Fusion Systems, others
 - Started within the past few years, great concepts

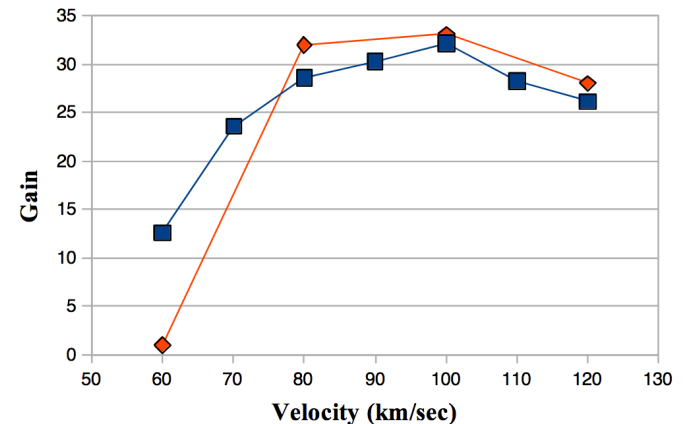
The Plasma Liner Experiment (PLX) at LANL seeks to demonstrate the formation of spherically imploding plasma liners as a driver for magneto-inertial fusion (MIF)

LANL PI: Samuel Langendorf



Hsu et al. IEEE Trans. Plasma Sci 2012

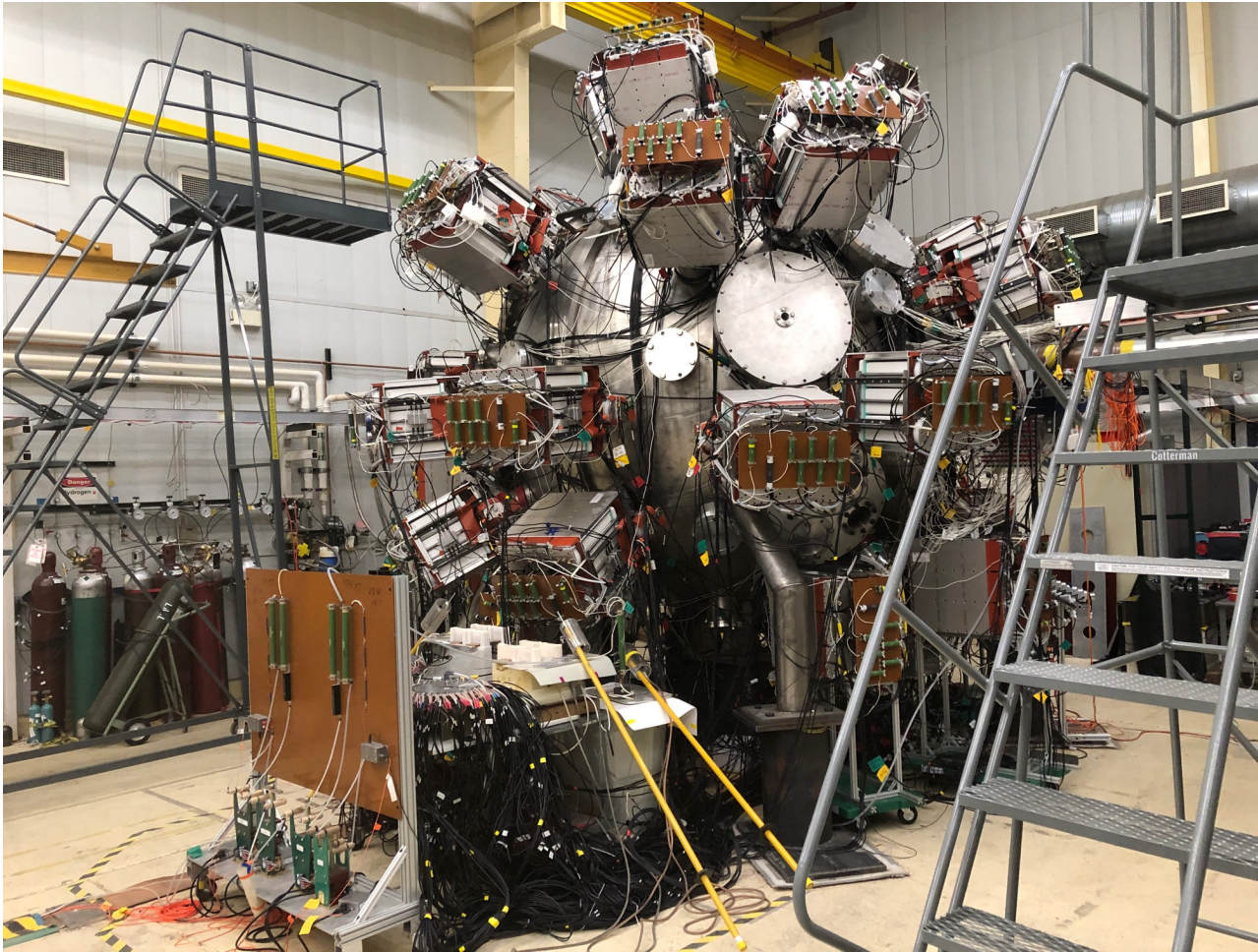
- Spherical MIF embodiment
- Access to high implosion velocities 50+ km/s
- Standoff plasma liner and target: no repetitive HW destruction



Simplified simulation results by Knapp et al., Phys. Plasmas 2014

PLX has completed an upgrade to house 36 plasma guns in a spherical configuration

LANL PI: Samuel Langendorf



- 9 ft diameter chamber
- 36 guns
- 254 total spark gap switches
- Stored energy ~ 200 kJ
- Nominal voltage ~ 4.5 kV
- Peak current all guns ~ 20-25 MA

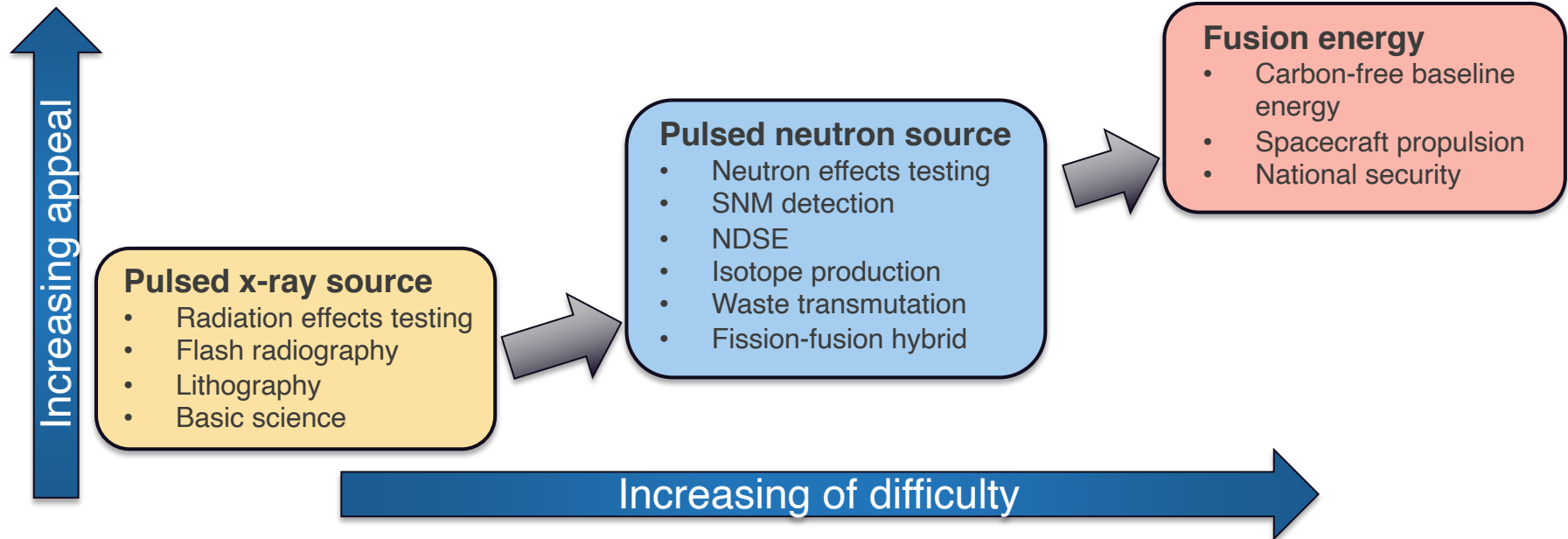
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EST. 1943

 **HYPERJET FUSION**
CORPORATION

A new heating and compression approach is being investigated to create hot dense plasmas*

LANL PI: Thomas Weber

*Currently funded to develop pulsed x-ray sources for NNSA



Benefits of this R&D path:

- Each development phase yields a marketable "product"
- Improving each previous "product" naturally leads to the next level (crawl, walk, run)

Further unique or attractive features of this concept

LANL PI: Thomas Weber

- Magneto-inertial approach
 - Low driver power, cost, complexity, and size (compared to ICF drivers)
 - No laser drivers (e.g., NIF) or intermediate storage (e.g., Z)
 - Relatively simple, efficient pulsed power drivers
 - Lower total energy requirements than magnetic confinement fusion approaches
 - More compact plasmas, higher power densities, lower reactor cost
 - Low costs and small scales (potentially portable) enables rapid iteration and development timeline (\$M's / years vs \$B's / decades)
- Modular design
 - Increasing energy is straightforward with low incremental cost
- Very high temperatures possible (several 10s keV)
 - Hard x-ray spectral output (for use as an x-ray source)
 - Higher fusion reactivity for higher DT neutron intensities (neutron source)
 - Advanced fusion fuels possible (fusion energy)